Geographic Information Technology Training Alliance (GITTA) presents:

Spatial Analysis of the Reality

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1. Spatial Analysis of the Reality

Introduction to the lesson

The understanding of spatial organisation at the Earth surface is the major and certainly the unique common concern among geoscientific disciplines. At different scales and for various spatial extents this preoccupation conducts to several specific questionings:

Learning Objectives

- How surface properties of a phenomenon are distributed throughout this region?
- What is the spatial distribution pattern of properties resulting from interactions between phenomena?
- How can this phenomenon or this process be modelled in space?
- How and Why a spatial distribution pattern changes with time?
- What will be the properties of a phenomenon and its distribution pattern in the future?

1.1. Introduction

To answer to such fundamental queries about the human environment organisation it is necessary to access to:

- A set of relevant information about the study subject (study area).
- Methods and techniques for analysing this information with specific objectives:
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    - Exploration: What?
    - Modelling: Why? How?
    - Acting, forecasting and planning: And then?

Objectives of spatial analysis

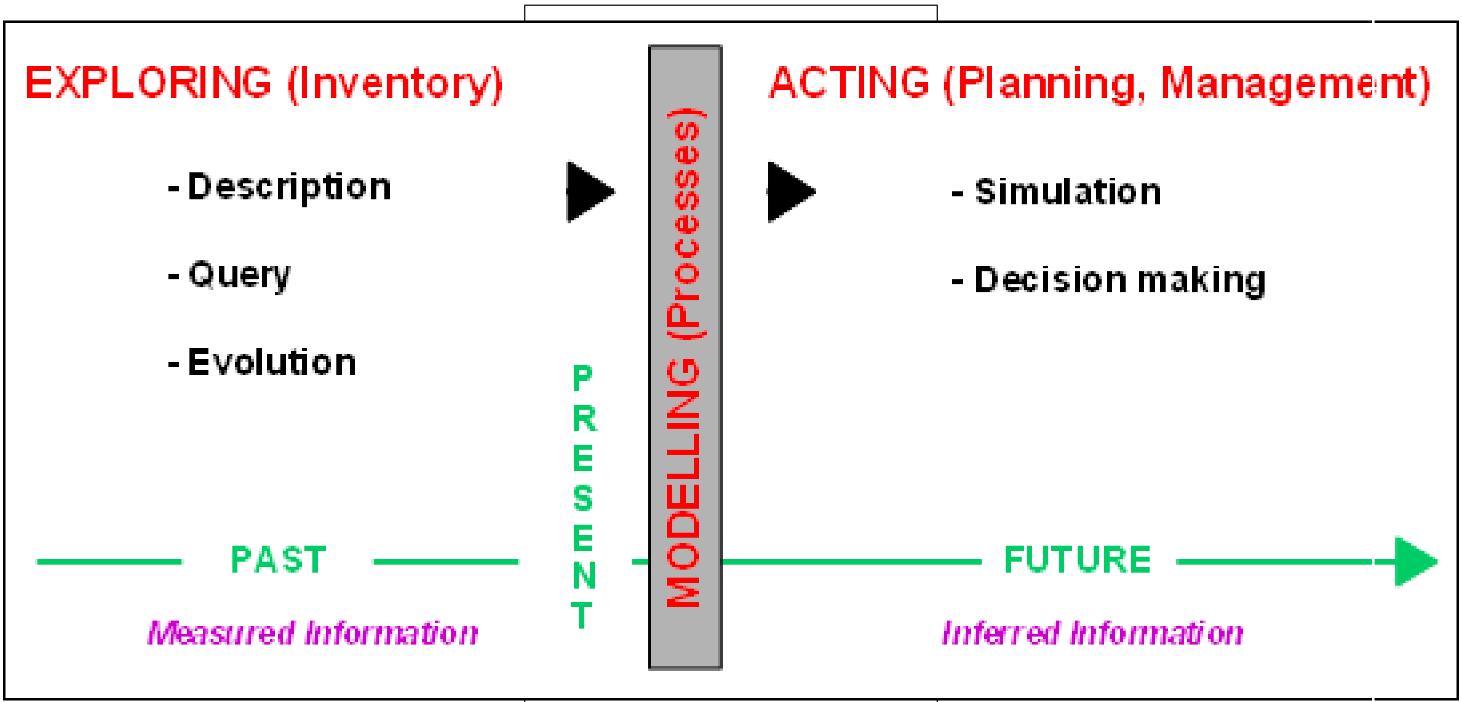

Figure 1.1

Geographic Information Science (often called Geomatics or Geo-processing) and its operational environment –the Geographic Information System (GIS- offers methodological processes (made of methods, techniques and tools) to construct and to exploit the geographic information. Spatial analysis (SA) is obviously concerned with the exploitation stage. However, as seen and illustrated in the Basic Level of this GITTA course, numerous interactions take place between the construction and the exploitation process. Let us recall some major steps.

Major steps in the construction and exploitation processes

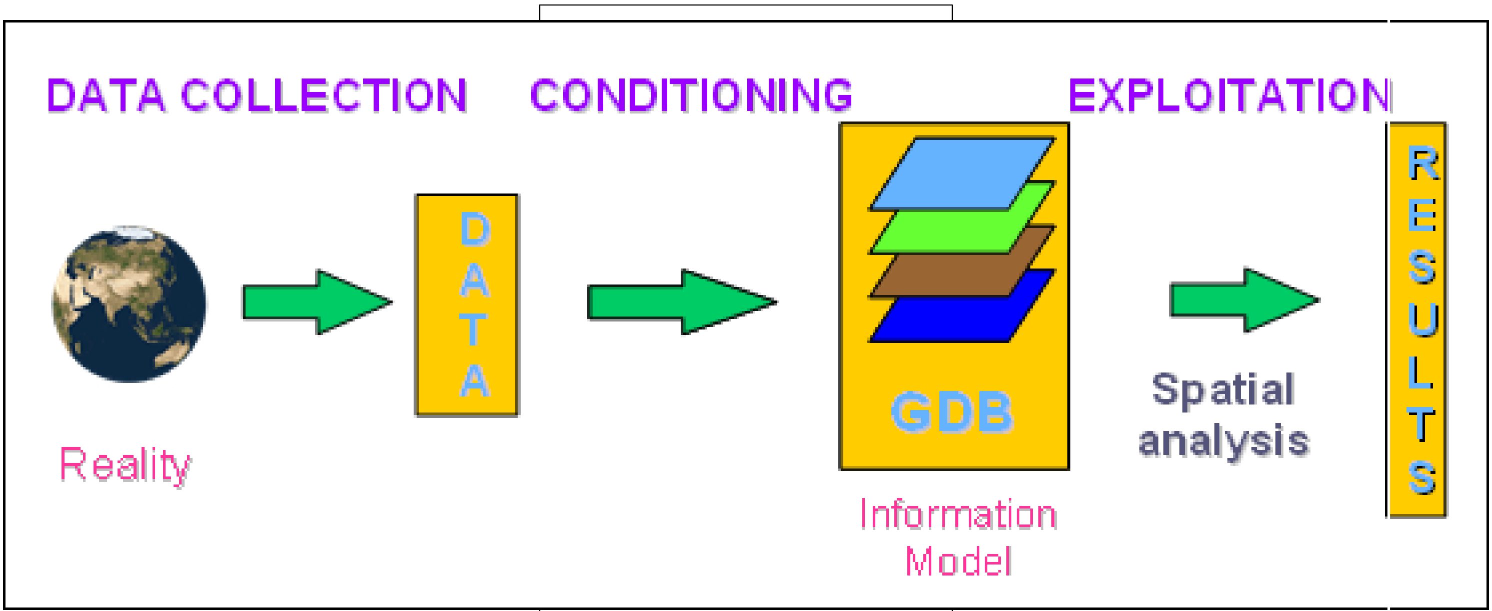

Figure 1.2

1.1.1. Construction of geographic information

It is a long way from the reality to a geographic information model (GIM).

From the reality to a geographic information model

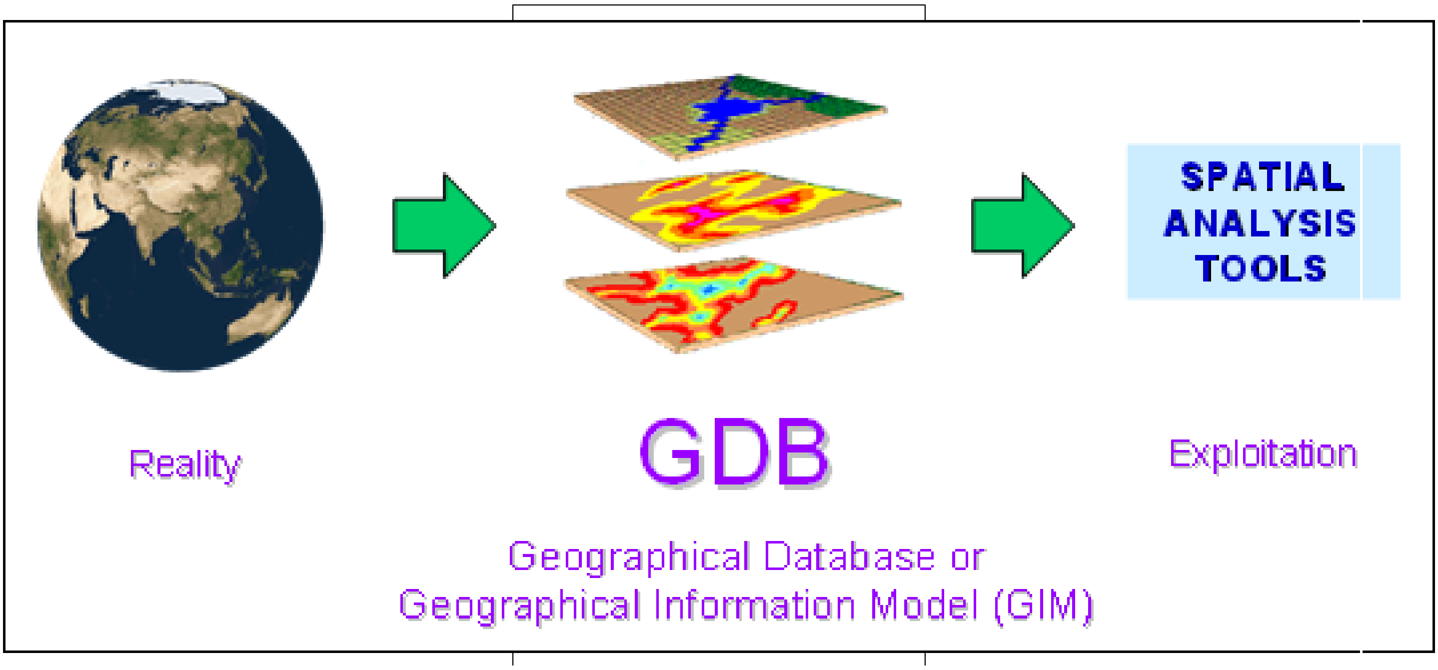

Figure 1.3

Modelling the reality (B-SM)

What to retain from the complexity of reality?

Anything relevant to the objectives of the study, but in a structured way.

From the real world to a model of the reality

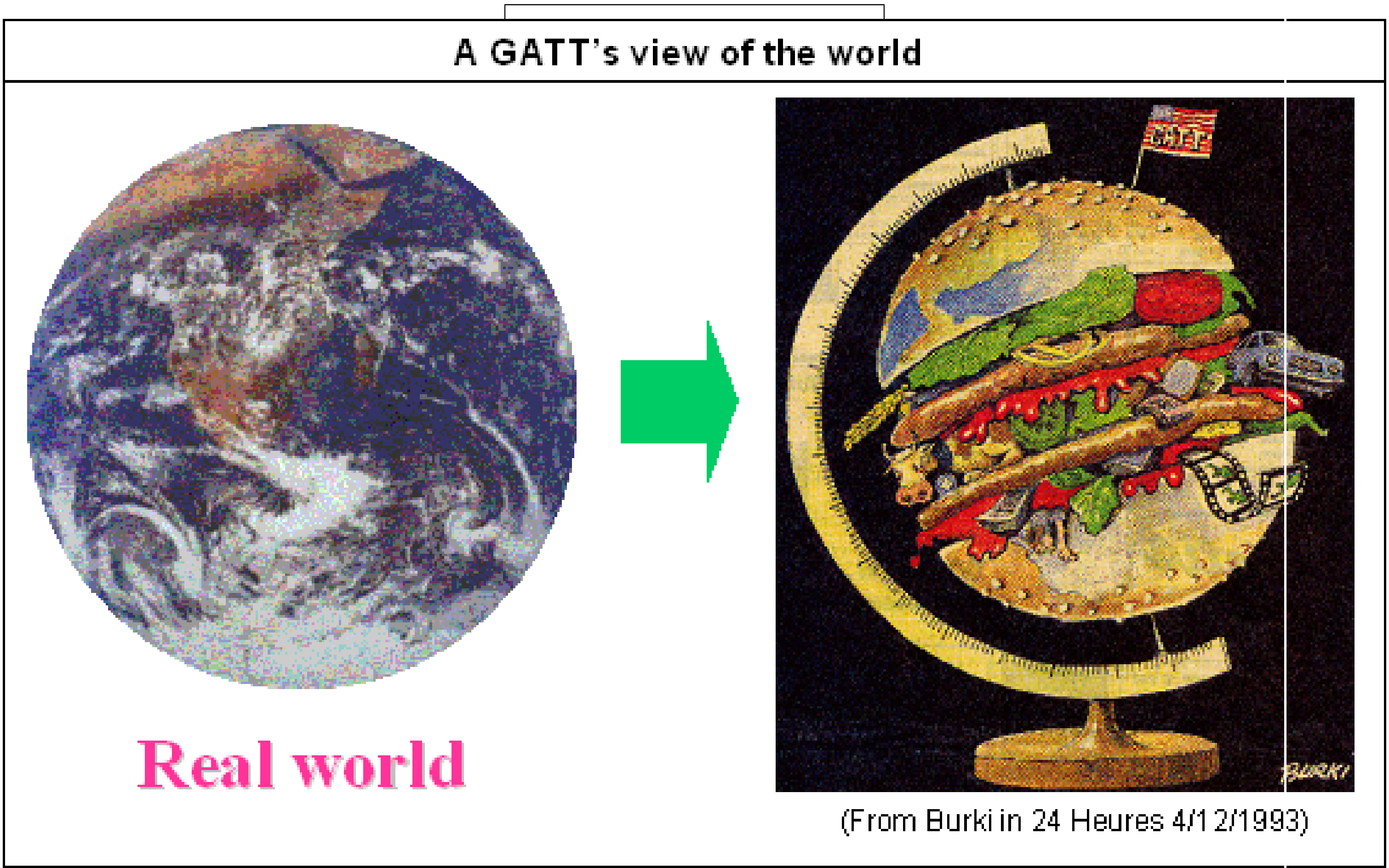

Figure 1.4

What are objectives of the study?

To answer to this obvious but tedious question, one should identify:

- The objectives of the exploitation
- All phenomena involved
- Concerned spatial features according to the spatial scale of investigation
- Concerned time-span: static or dynamic

Objectives of spatial analysis

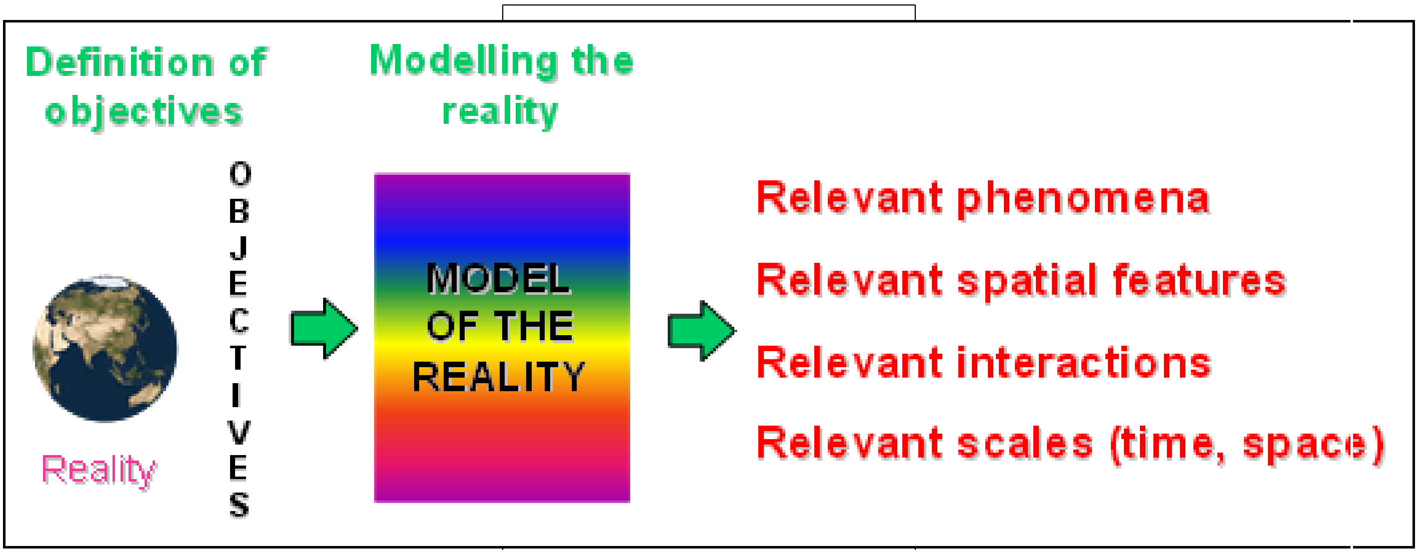

Figure 1.5

How concerned elements of the reality can be organised in a structured set? This leads to the definition of information content and its structure:

- Type of spatial units of description (measurement): predefined units (objects in object mode) or arbitrary units (cells in image mode)
- Identification of spatial units: individual objects or definition of cell size (resolution)
- Richness of thematic content: relevant indicators, level of measurement
- Richness of time content: period of investigation, time intervals

Collecting data from the reality (B-DC)

What are available sources of data for the production of a relevant model of geographic information (Geographic Database, GDB)?

To answer to this complex and time consuming query, one should identify and verify:

- Adequate sources: with thematic, geometric and time contents
- Source types: terrain, documents, existing GDB
- Relevancy of information content: thematic, geometric and time contents
- Quality of information content: thematic, geometric and time contents

Sources of data

Figure 1.6

How to design a methodological process to collect and to produce relevant numerical data?

Data collection and production of numerical data require knowledge and expertise about the nature of the source and the phenomenon:

- Acquisition instruments and specific techniques
- Data sampling procedures for representativeness
- Data digitising methods to produce numerical data

From terrain to geo-data: Set-up of acquisition procedure

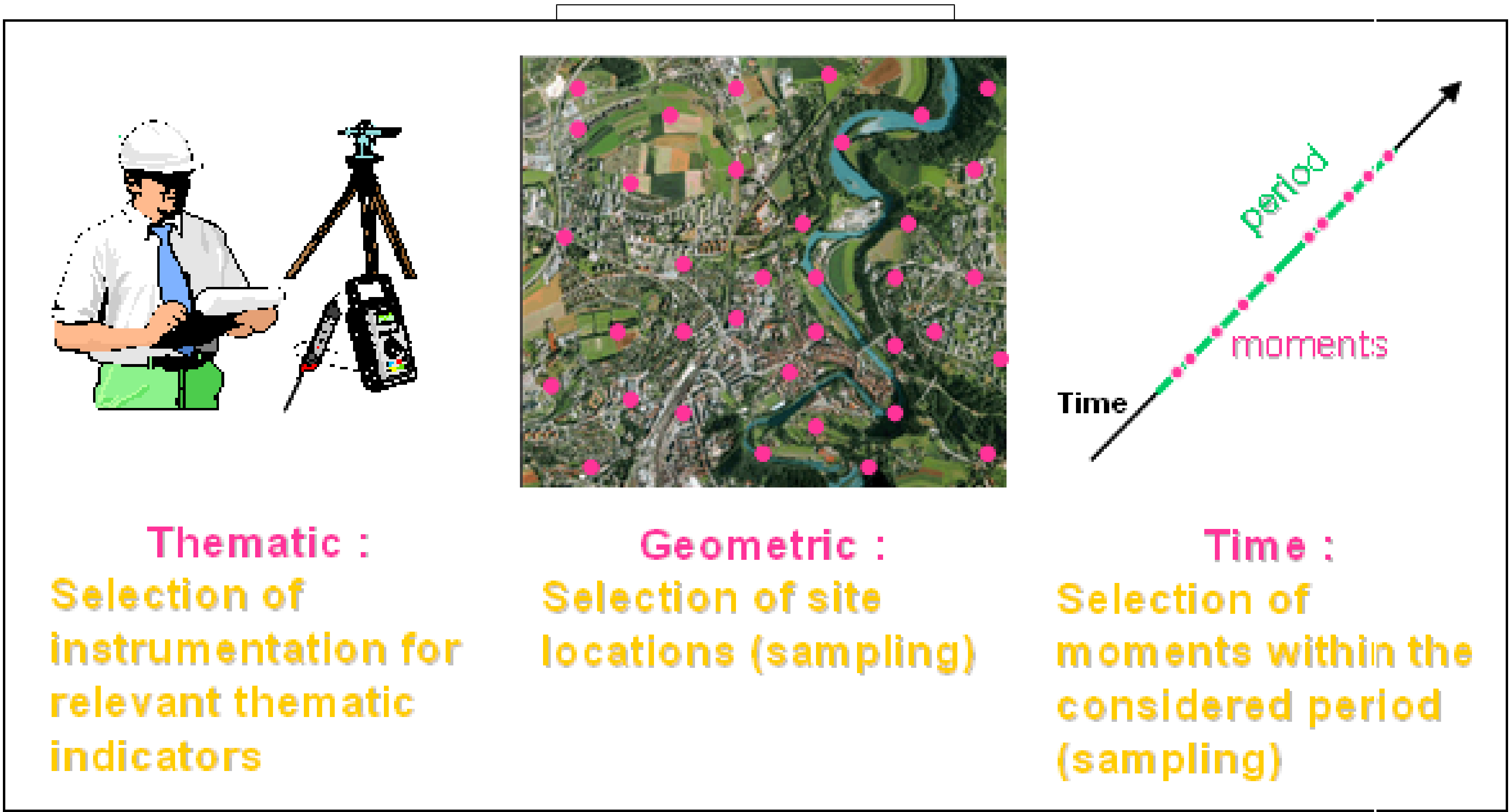

Figure 1.7

Conditioning and regionalising data (B-AN, Lessons 2 to 4)

How to produce a relevant model of geographic information from the collected set of data?

Sampled data sets do not fully express the distribution of phenomena properties throughout space and time. They have to be conditioned to become Geographic Information, an expression of the model of reality:

- Deriving significant indicators from collected variables
- Estimating individual properties of spatial units (objects or cells) based on sampled locations: Regionalisation
- Estimating properties of time series from the original sampled time interval

Organising and managing Geographic Information (B-DM)

How to efficiently organise Geographic Information (GDB) for reliable updates and fruitful exploitations?

The geographical database should be organised and structured in a way that allows safe and reliable maintenance and a multidimensional access to information for its exploitation:

- Maintenance of the meta-information
- Control of GDB integrity
- Planning updates of phenomena properties and their related spatial entities
- Allowing access to information for multiple types of exploitation

1.1.2. Exploitation of geographic information

The exploitation of geographic information is aimed for exploring, modelling and forecasting spatial processes from the model of reality. This is where **Spatial Analysis (SA)** takes place. However methods of spatial analysis are already used for the construction of geographic information, mainly during the conditioning stage for regionalisation purposes. The spatial dimension of information allows original and rich components belonging to the reality.

Components of the spatial dimension to be exploited with spatial analysis

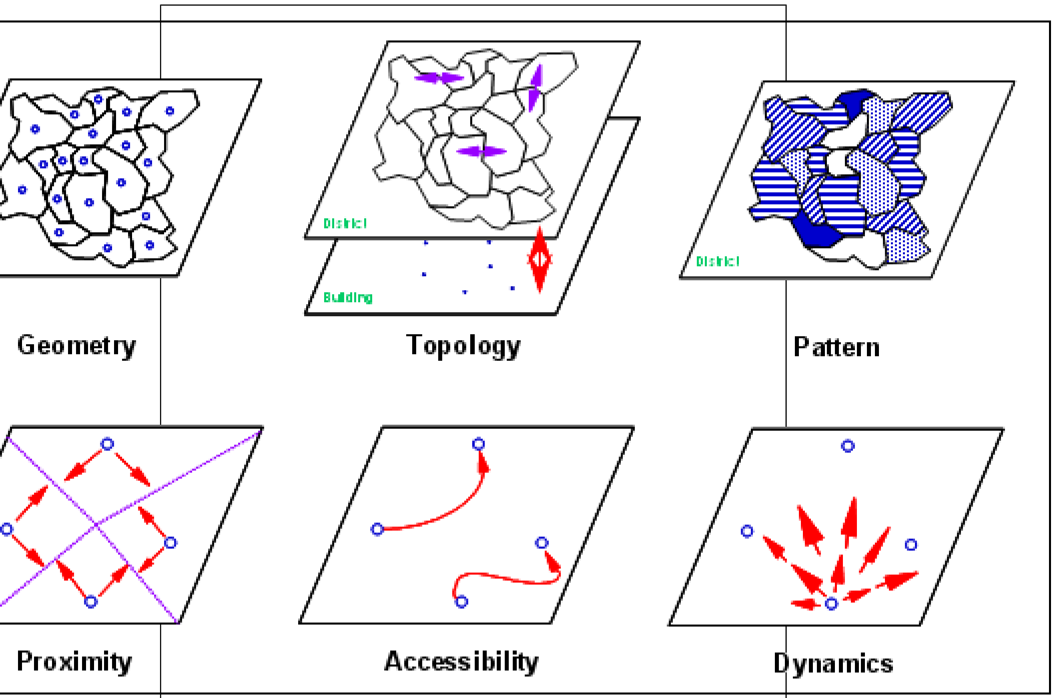

Figure 1.8

Exploration and modelling objectives are embedded in the organisation of B-AN Lessons. Their contents are structured according to the nature of phenomena and to exploitation tasks. According to the objectives of the exploitation, space and its spatial relationships can be modelled in different manners, from a “simple” homogeneous surface to a heterogeneous volume with anisotropic properties:

- As an *isotropic plane surface*: space is simply considered as an homogeneous surface with thematic property distribution only ruled by euclidian geometry (linear plane distance influencing accessibility, proximity and dependency).
- As an *isotropic skewed surface*: space is considered as an heterogeneous surface with each location influencing differently the distribution of thematic properties as well as the proximity and the accessibility. Space is modelled as a skewed surface expressing an individual “isotropic friction rate” at each location. Distance is therefore no longer linear but symmetrical.
- As an *anisotropic skewed surface*: space is considered as an heterogeneous surface but with an individual “anisotropic friction rate” at each location. Distance is therefore no longer linear nor symmetrical.
- As an *anisotropic skewed volume*: space is considered as a volume rather than a surface. Distribution of properties are modelled in 3 geometrical dimensions, sometimes required for analysing atmosphere, hydrosphere or the lithosphere.

Modelling spatial properties in different manners

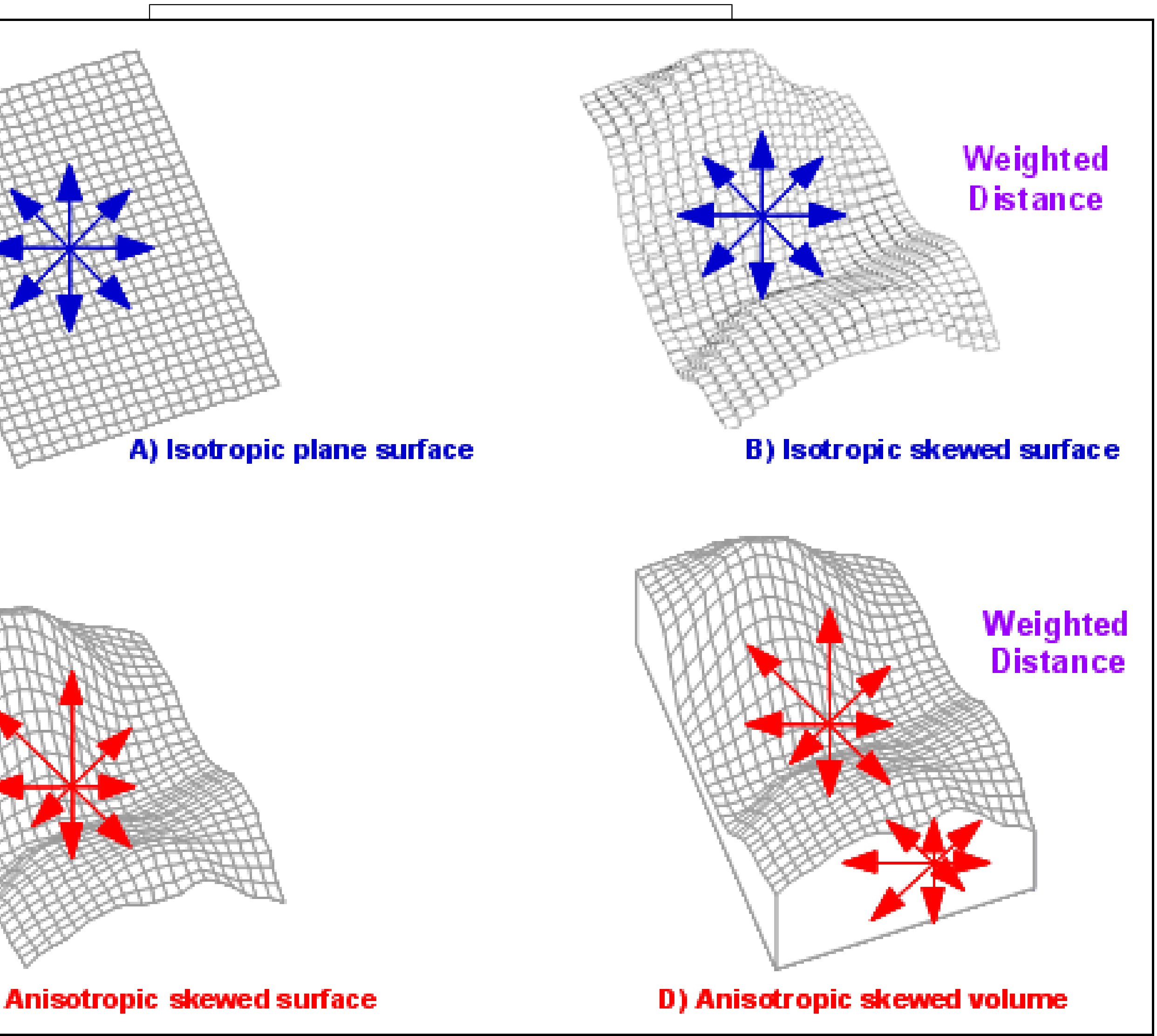

Figure 1.9 (MEA 5-11)

Exploration of geographic information (B-AN, B-PR)

What is the spatial distribution of properties throughout the study area? What are relationships between spatial features and within their thematic properties and their change?

To answer to these rich and complex questions, one needs to consider the nature of spatial distributions and the objective of exploration for the design of an appropriate exploration process:

- The spatial distribution of phenomena according to their nature (continuous, discontinuous). Tools and methodologies to describe their distribution and to relate properties of spatial features (**B-AN Lessons 2** and **3**)
- How to describe relief properties of space based on its elevation properties (DEM)? Numerous methods for deriving relevant indicators of relief and for partitioning space into terrain features (watersheds, shape types ...) are proposed. They are terrain analysis methods (**B-AN Lesson 4**)

- The selection of spatial features or the description of their specific properties. Spatial Query is certainly the most obvious but also the most frequent exploration objective. It allows selecting spatial features from the GDB based on various thematic and geometric criteria. In object mode spatial query makes used of powerful tools proposed by SQL and GQL languages features (**B-AN Lesson 5** and **B-DM Lesson 4**).

1.2. Where to go further?

Entry

At the basic level the spatial analysis Module (B-AN) has already covered a wide range of methods and processes designed to explore the spatial dimension of information. There is however much more to discover for an efficient exploitation of geographic information. Remember that our objective is to answer to questions about the real world and its evolution, many of them are complex and laborious.
This intermediate module (I-AN) proposes a series of Lessons about either an in depth view of already covered themes or new themes. Of course only a limited number of topics was selected from the wide range of spatial analysis methods. Lessons are organised as follow.

1.2.1. In depth look at already covered themes

There are 5 themes currently available:

Lesson 2, Discrete spatial distributions

As previously discussed in the Lesson 2 of the Basic Spatial Analysis Module (B-AN), spatial features are identified from the property distribution of discontinuous (discrete) variables. This Lesson 2 now concentrates on the spatial distribution of **zonal or areal features**.
In the first Unit tools are proposed to investigate the degree of **spatial dependency** that rules the distribution of zonal features and their thematic properties throughout the whole extent of the study area. Similar to continuous spatial variables, there are autocorrelation methods measuring the degree of spatial dependency. The second Unit focuses on the description of zonal features within their neighbourhood, this at different spatial scales. At the regional scale numerous **indices of structure** are illustrated, as at a local scale for **indices of texture**.

Lesson 3, Continuous spatial variables (not yet finished)
This Lesson focuses on the central concept of regionalised variables, a key concept in geostatistics. It first takes an empirical approach to link sampled observations with variography and kriging interpolation methods. It then relates variography with properties of random functions and variables.

Lesson 4, Terrain analysis

Based on the distribution of elevation (Digital Elevation Model), numerous indices can be derived for the description of **terrain and topographic properties** of a study area. This Lesson 4 illustrates a selection of derived indices and spatial features exploited in three different applied fields.
In the first Unit the production of drainage networks is presented and discussed in the context of **hydrological applications**. The production of several **engineering measurements** (profiles, surface, volume …) is then proposed in the second Unit. The topic of **visibility analysis** is finally presented in the third Unit, including the study of factors influencing the visibility of a landscape, such as solar illumination and atmospheric content.

Lesson 5, Accessibility

Accessibility describes spatial distance relations between objects. The fundamental concepts of distance relations and networks for the constrained object relations were given in the **basic accessibility Lesson** (B-AN).
In the first Unit of this Lesson **cost surfaces, constrained surfaces** and their applications are introduced. In the second unit **network analysis** (shortest path, travelling salesman problem) and corresponding algorithms are presented.

Lesson 6, Suitability

The topic of Suitability analysis was already presented in the Basic Module of Spatial Analysis (B-AN, **Lesson 7**). The suitability of a location refers to the ability of a location on the basis of one or several objectives and criteria. It results from a decision process in which decision rules should be elaborated. In many situations this process is complex due to the difficulty to set sharp limits between suitability and unsuitability, due to the uncertainty present into information and because of conflicting objectives. This Lesson presents two major topics related with this complex process. In the first Unit the application of a **fuzzy overlay** for non-boolean decision rules is introduced. In the second Unit methods for the **multi-objective** analysis are presented.

Lesson 7, Introduction to Time Change and Spatial Dynamics

As an introduction to this topic, lesson 7 presents a variety of contexts in which time changes occur. In order to identify specific objectives and methodologies within these contexts, this Unit proposes a list of key factors controlling contexts of time analysis. This leads also to isolate two complementary approaches: the evolution of thematic properties of spatial features (Thematic changes) and the evolution of spatial distribution and patterns, that includes the analysis of movements in space (Spatial dynamics).

Lesson 8, Thematic Change Analysis

This lesson 8 proposes a framework to organise potential methods with respect to the objectives and to the information context of the change analysis. It is structured into three sections: the production of change indices, the description of the behaviour of time series, and multivariate time change analysis. Such approaches are mainly concerned with the thematic changes of the properties of spatial features, both at univariate and multivariate levels.

Lesson 9, Spatial Change Analysis

This lesson 9 presents several methodologies to investigate these two approaches. The spatial change analysis concentrates on how space evolves throughout time by the identification of local and regional change components. It makes use of the change indices presented in **lesson 8** and explores the spatial distribution of these changes in terms of intensity and direction of change. On the other hand, the modelling and simulation of movements in space deal with the process of space accessibility. Cellular automata and diffusion models offer tools for analysing spatial growth processes, whereas accessibility processes can be analysed with the use of concepts such as the cost distance, frictions, barriers, and anisotropic properties of space.

1.2.2. New topics

One new topic should be included sooner or later:

Lesson 10, Error propagation (not yet finished)
Uncertainties and their propagation within the spatial analysis process is certainly a very sensible but very complex issue. As they affect results of an analysis, they should be carefully tracked and evaluated for estimating the **degree of uncertainty** of produced results. This Lesson presents **concepts** behind the theory of uncertainty and error propagation. It identifies **sources of uncertainties** within geographic information and its process. It illustrates several situations as well as methods of evaluation.